QUESTION FROM THE CLASSROOM

By Bob Becker

Q. I saw this video on YouTube that showed a guy breathing in a gas from a balloon. Unlike helium, instead of making his voice higher, this gas made his voice much lower. It was amazing! What was the gas?

A. The gas was a compound called sulfur hexafluoride. As the name implies, its molecules are made of one sulfur atom and six fluorine atoms (Fig. 1). One might think that a compound made of sulfur (used in making matches and gun powder) and fluorine (the most reactive nonmetal) would be too dangerous to handle, let alone breathe in. But these two highly reactive elements form such a stable bond that the resulting compound is almost as inert as a noble gas—one of the gases listed in the last column of the periodic table (helium, neon, argon, etc.).

That does not necessarily make it safe to breathe in! The first hazard associated with breathing in helium and sulfur hexafluoride is that impurities may be present in the tank storing the gas, which may include oils in the valves and regulators or toxic hydrogen fluoride gas.

The second hazard is that these gases do not provide oxygen, which our body depends on 24/7. You might think then that breathing in one of these gases for a short while would be no worse than just holding your breath for that same amount of time. Actually, when you hold your breath for 15 to 20 seconds, you are immediately aware that something is wrong and your body instinctively feels the urge to gasp for a fresh breath of air. Surprisingly, that gasping reflex is not triggered by the lack of oxygen in the blood but by the buildup of carbon dioxide in the bloodstream because you didn't breathe out!

ACS STAFF

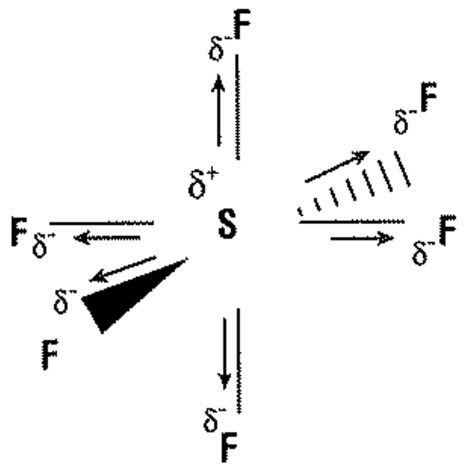

Figure 1. Molecular structure of sulfur hexafluoride. Electrons move from the center of the molecule to the periphery (red arrows), creating a small charge imbalance that makes the center slightly more positively charged (δ^+) than a single sulfur atom and the fluoride atoms in the periphery slightly more negatively charged (δ^-) than single fluorine atoms. But overall, the molecule is nonpolar because all these charges cancel out.

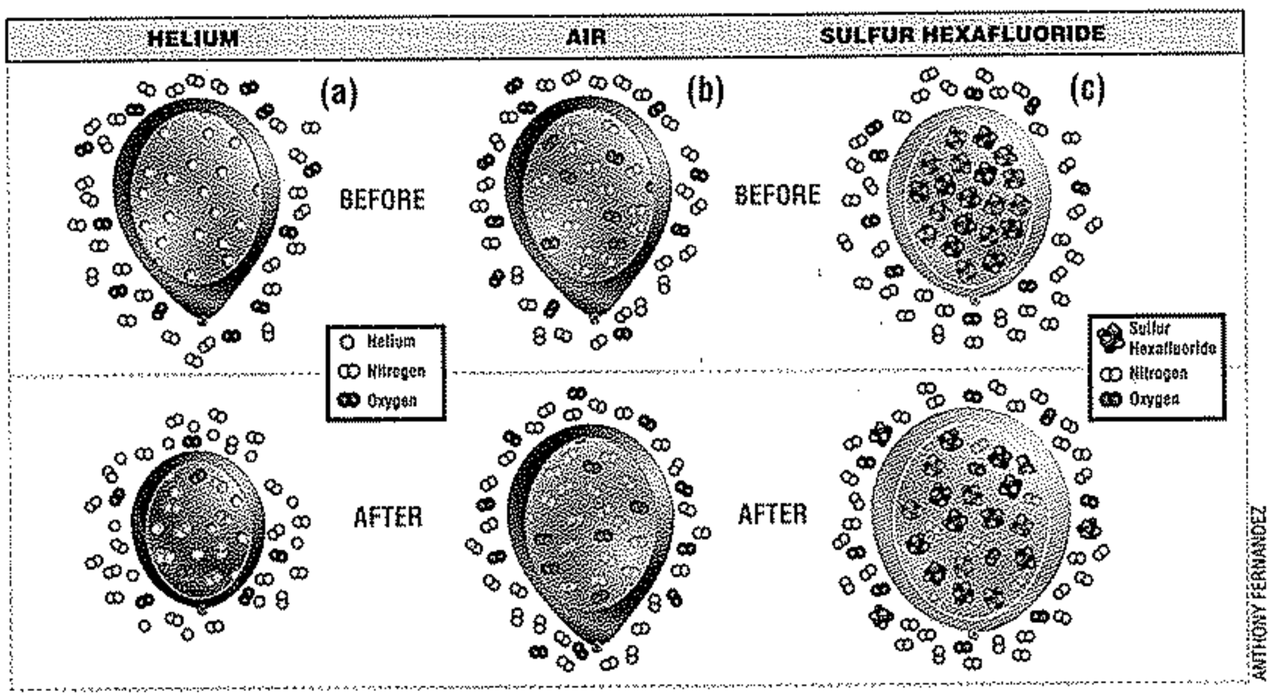

Figure 2. (a) A balloon filled with helium gas tends to deflate quickly as more helium leaks out than oxygen and nitrogen molecules from the air enter the balloon; (b) A balloon filled with air stays more or less the same from one day to the next; (c) A balloon filled with sulfur hexafluoride inflates because only a few sulfur hexafluoride molecules leak out while relatively more oxygen and nitrogen molecules from the air enter the balloon.

So, say you breathe in helium, talk funny, laugh a little then breathe out—expelling all the carbon dioxide from your lungs—and then breathe in some more helium, sing a Munchkin song, laugh some more, breathe out some more carbon dioxide … . All the while, you don't breathe in any oxygen and are completely unaware of the fact that you are actually suffocating, which can happen in a very short period of time. This is why some people tend to overdo helium breathing and end up passing out, which can make them fall without warning and cause injury.

Sulfur hexafluoride has some rather peculiar properties. The fluorine atoms have a very strong attraction for electrons—which means that the electrons shared between the sulfur and the fluorine spend disproportionately more time near the fluorine atoms, giving them a partial negative charge. But because the molecule of sulfur hexafluoride is completely symmetrical, these polar bonds all cancel out and create a nonpolar molecule (in which the electrons are symmetrically distributed—mostly on the fluorines). This explains why sulfur hexafluoride is a gas at room temperature and remains so all of the way down to –64°C.

Perhaps the most remarkable effect associated with sulfur hexafluoride can be observed when the gas is put into a balloon and just left there (Fig. 2). A balloon filled with helium gas tends to deflate quickly as the helium leaks out, and a balloon filled with air stays more or less the same from one day to the next. But a balloon filled with sulfur hexafluoride will grow in size!

A helium balloon decreases in size over time because the helium atoms inside are moving so fast that they can leak out more quickly than the air molecules outside can leak in. An air-filled balloon maintains its size because the air molecules inside leak out at about the same rate as the air molecules outside leak in. And a balloon filled with sulfur hexafluoride increases in size over time because the air molecules outside leak into the balloon more quickly than the sulfur hexafluoride molecules inside leak out. Cool, huh?

The original YouTube video can be found at http://www.youtube.com/watch?v=vcVMjGRzDz8&feature=related.